

Chapter 5: Practical Approaches For Acoustic Construction

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5-1 Using This Chapter

This chapter contains discussions and illustrations of practical construction methods and typical details for achieving sound isolation, noise control, and good room acoustics. The principles behind these techniques have been discussed in Paragraph 3-5, Acoustical Considerations. The examples presented are not solutions to all problems, but aids to understanding how to apply the principles to achieve a Band Practice Facility that performs successfully. The illustrated methods should be useful to architects in developing Final Designs for band facilities, and to band personnel and Facility Engineers doing minor renovations and improvements to existing facilities.

5-2 Sound Isolation

Isolation depends on the design and execution of all barriers that separate one room from another. That includes floors, roofs and ceilings, walls, as well as door and window assemblies. Balanced performance is the goal. If a portion of a barrier is weaker than the remainder (for example, an STC 35 door in an STC 65 wall), the inferior portion controls the isolation achieved. Even before these construction considerations, planning for appropriate adjacencies and separations, as discussed in Sections 3-4 and 3-5, should have been applied, as the most cost-effective means to obtain isolation.

This discussion presents approaches and details for sound-isolating construction in the form of discussions of specific room types. But the methods described for a specific space are applicable generally to isolation problems of similar scope. Throughout this discussion, refer to Table 5-1, which indicates the performance that can be expected of well-sealed barriers of the respective types. Also see Tables 5-2 and 5-3, which suggest constructions adequate for different room types and combinations of materials, discussed in detail below.

A. Individual Practice Rooms

Individual Practice Rooms, from 65 to 125 square feet in area, may have background noise up to NC-35 (see Paragraph 3-5.A), yet sound produced in the rooms may reach 90dB. Thus, by first approximation, the barrier between adjacent practice rooms should reduce the sound by at least 55 dB, or should be rated STC 55. This does not guarantee inaudibility, which would require an "overdesign" by 10 to 15 dB, but it does represent a reasonable goal.

Table 5-1 Typical Performance Ranges of Sound Isolating Constructions

	STC*
Floor-Ceiling** Constructions:	
Wood joist floors without ceiling	20-30
Same with rigidly attached ceiling	30-40
Same with resiliently attached ceiling	45-55
Concrete slabs/decks without ceiling	35-55
Same with suspended ceiling	50-65
Double (floated) concrete slabs	55-70
Double concrete slabs with suspended ceiling	65-80
Wall Constructions:	
Simple stud walls, with gypsum wallboard	30-40
Double stud walls, with gypsum wallboard	45-55
Demountable partitions, with gypsum wallboard	30-45
Simple masonry walls	35-55
Same with resiliently furred skins of gypsum wallboard	50-65
Double (tieless) masonry walls	60-75
Doors and Windows:	
Hollow core door and wood frame	10
Solid core or hollow metal ungasketed doors	15-25
Fully gasketed (acoustical) doors	30-50
Tandem doors in common wall	35-55
Tandem doors in sound lock	40-70
Typical single glazing or thermal double glazing	25-35
Special laminated acoustical glazing	35-45
Well-separated double glazing	40-55

*Note the limits of Sound Transmission Class (STC) measurements as a guide to performance in band facilities, as discussed in 3-5.A. See discussion of specific room types in this chapter for recommended STC levels.

* **All ceilings solid plaster or gypsum board; not acoustic tile which is inherently porous.

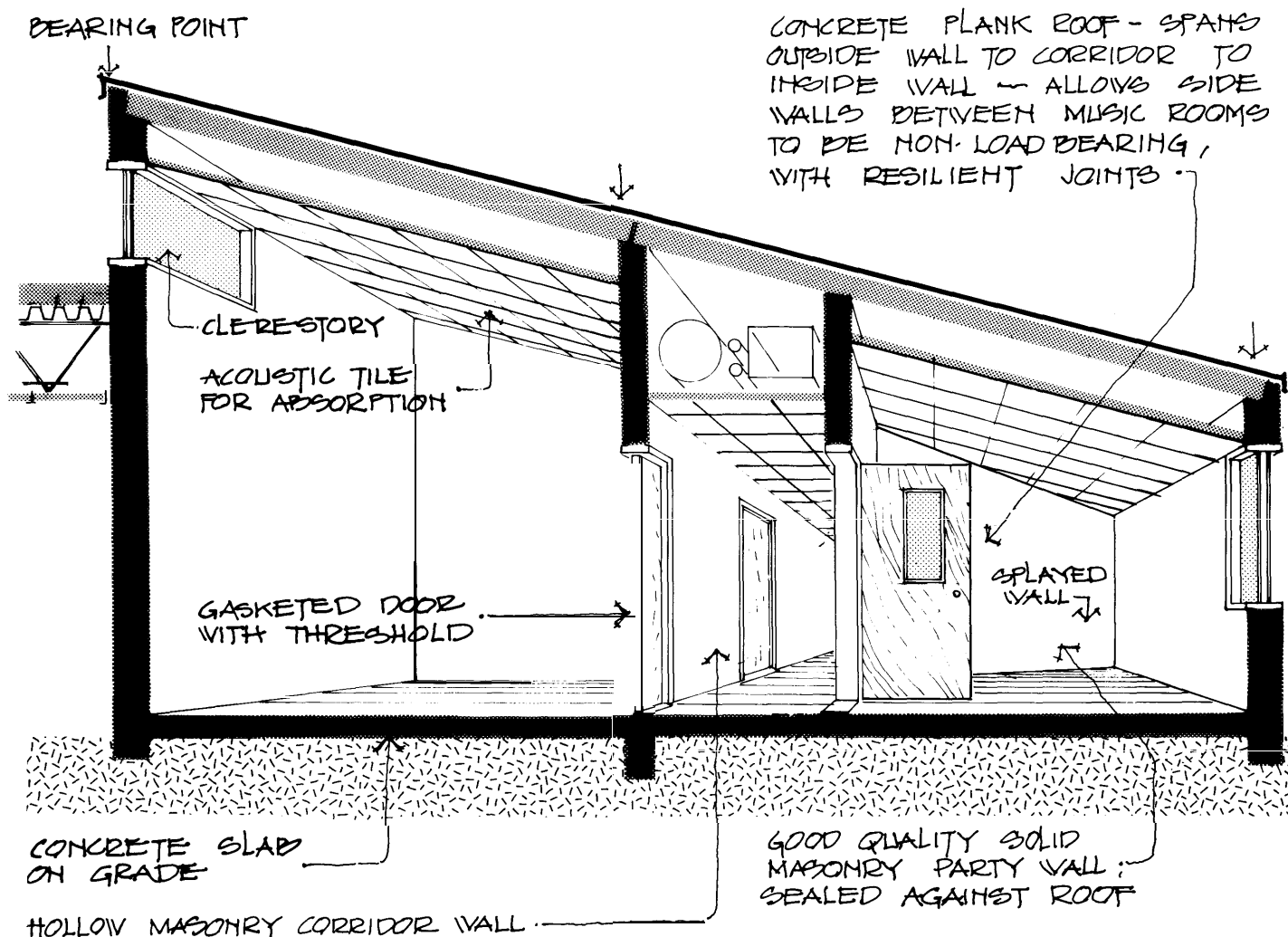


Figure 5-1. Section Through Typical Individual Practice Rooms

Figure 5-1 illustrates a typical practice room configuration. The building is concrete slab-on-grade to reduce sound transmission. Walls to corridors may be hollow concrete block, and walls between rooms should be solid or sand-filled. These party walls are shown splayed for sound diffusion as discussed in the acoustics section to follow. Clerestories and windows allow natural light and help

avoid a claustrophobic effect in the small rooms. Concrete plank spans from outside walls to corridor walls, so the walls between practice rooms are not loadbearing, and can have a resilient, flexible joint to the roof to reduce sound transmission. An acoustic tile ceiling is required for absorption, not isolation. The door is gasketed, with a raised threshold.

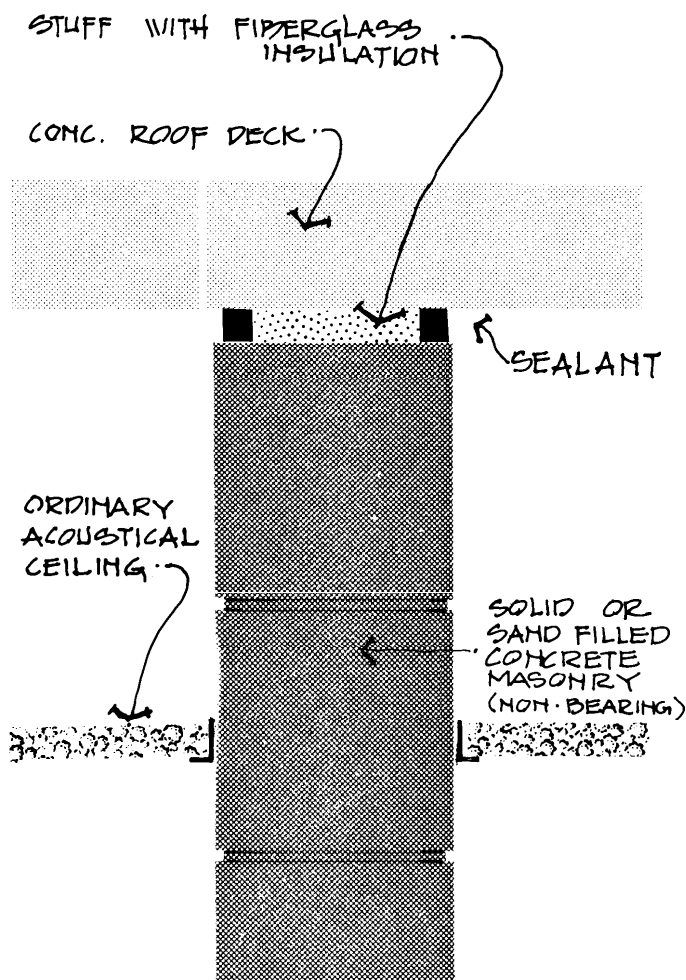


Figure 5-2. Minimum Wall Construction Required Between Individual Practice Rooms

A recommended construction to achieve this noise reduction between Individual Practice Rooms is shown in figure 5-2: 8" solid or sand-filled concrete masonry units with a resiliently filled joint to a concrete roof. The space between the top of wall and roof, between the sealant beads, is stuffed with fiberglass insulation. Similar units with resiliently furred gypsum board on one or both sides, are preferred. Tieless double masonry would be ideal.

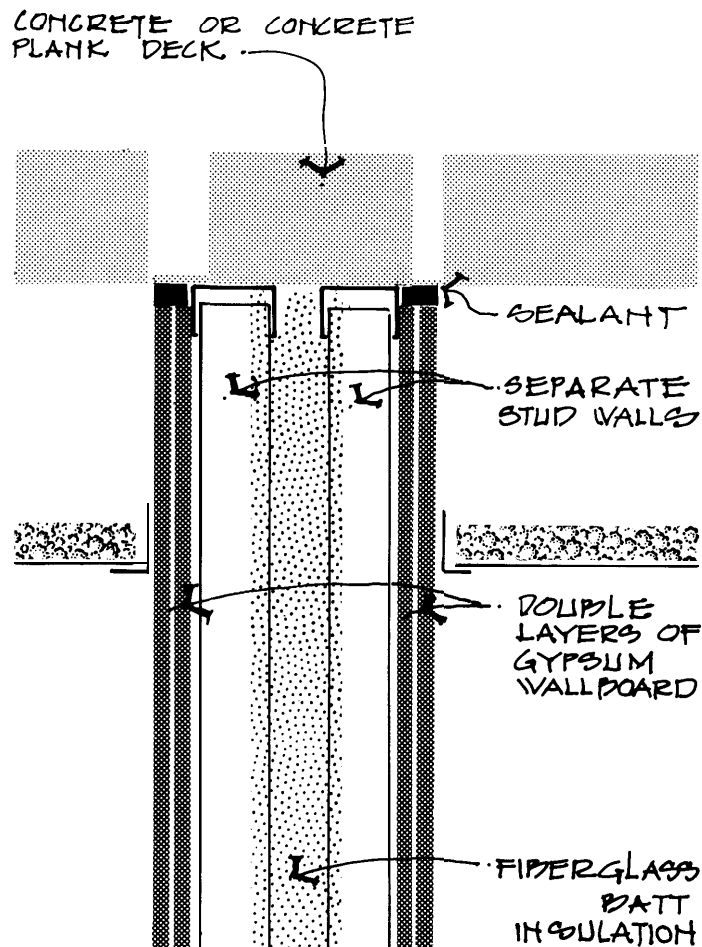


Figure 5-3. Gypsum Wallboard Construction Between Two Individual Practice Rooms (not recommended)

Because of their light weight (see Paragraph 3-5.A), stud walls, regardless of their STC ratings, generally are not recommended. Figure 5-3 is included only to show the type of stud wall that must be provided if masonry absolutely cannot be used. The wall shown has two separate rows of studs, multiple layers of gypsum board, and batt insulation. The roof illustrated is concrete, and sealant fills the joint between gypsum and concrete.

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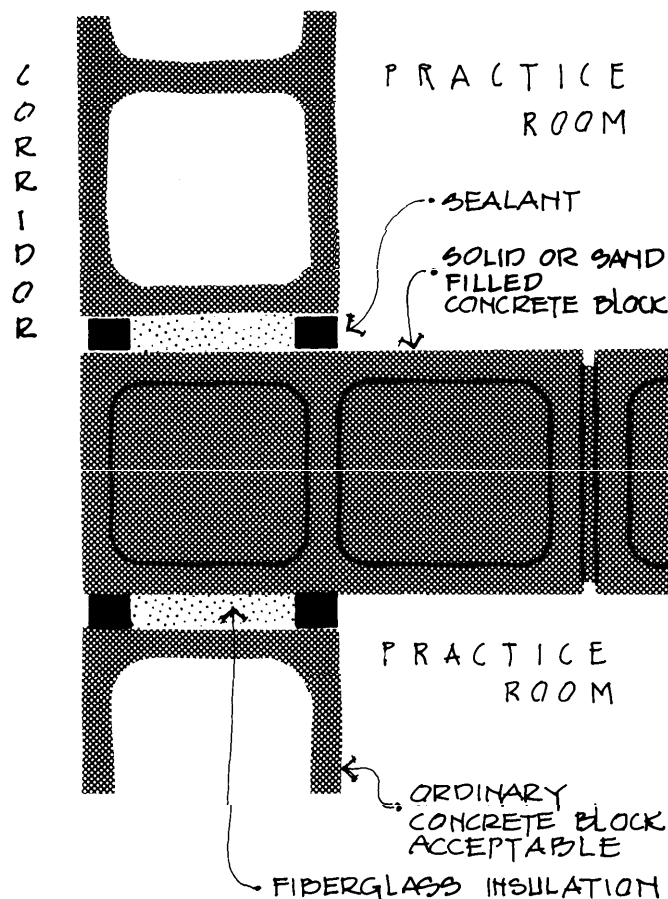


Figure 5-4. Party Wall and Corridor Wall Meeting

Corridor walls need not perform as well as walls between adjacent practice rooms, because they are in any case compromised by the doors. Almost any concrete masonry is adequate. However, a simple corridor wall must not be allowed to flank a superior party wall. Figure 5-4 demonstrates a recommended configuration with resilient joints where the corridor wall butts against the party wall ends, and fiberglass packed into the joint.

Roof construction for Individual Practice Rooms involves several possible combinations. The most likely roof constructions are concrete, concrete plank, and metal deck (with

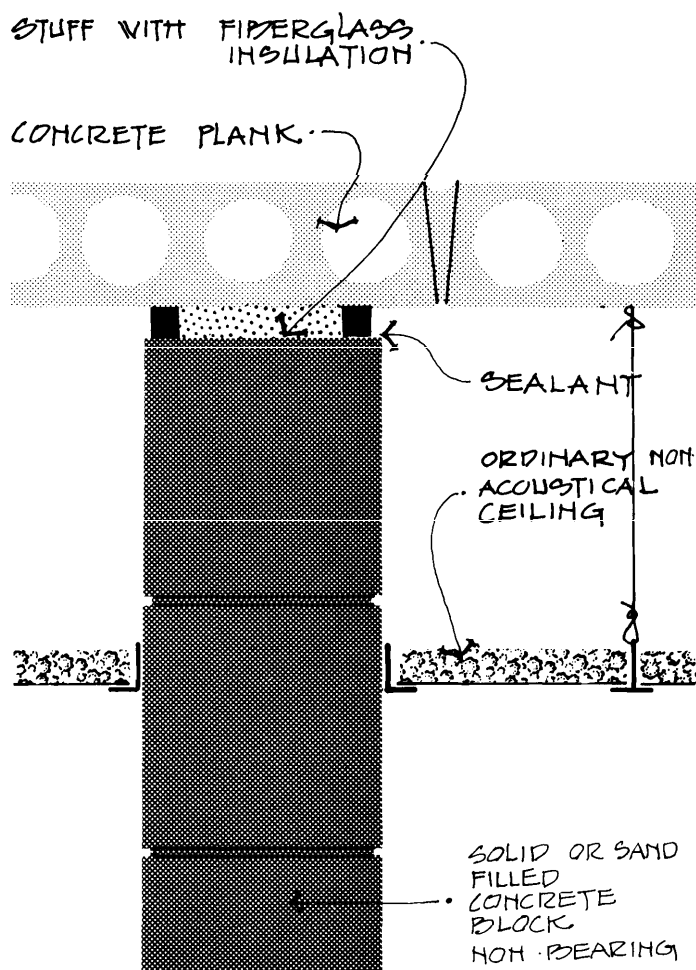
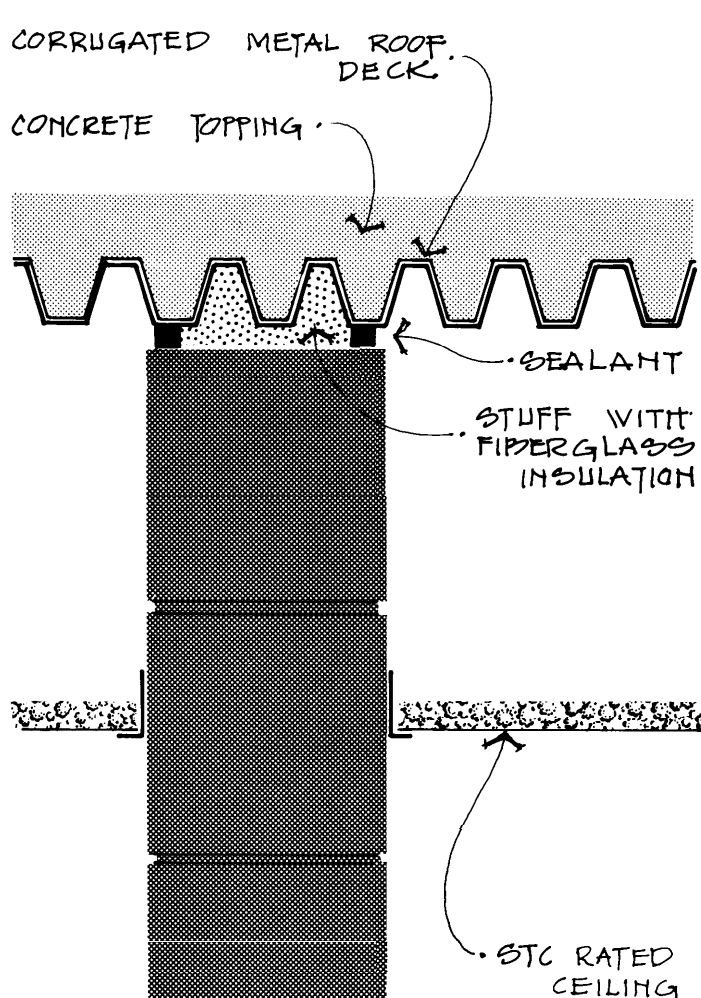


Figure 5-5. Masonry Wall and Concrete Plank Roof

or without concrete topping). Isolation performance decreases with decrease in mass, and with increase in stiffness (stiff materials carry vibrations more readily). Concrete is best, and metal deck without topping is worst.

A concrete or concrete plank roof (as in Figure 5-5) requires no further ceiling isolation measures in the case of Individual Practice Rooms. Only a regular acoustical ceiling (non-STC rated) is needed to provide absorption within the room, as a room acoustics provision.

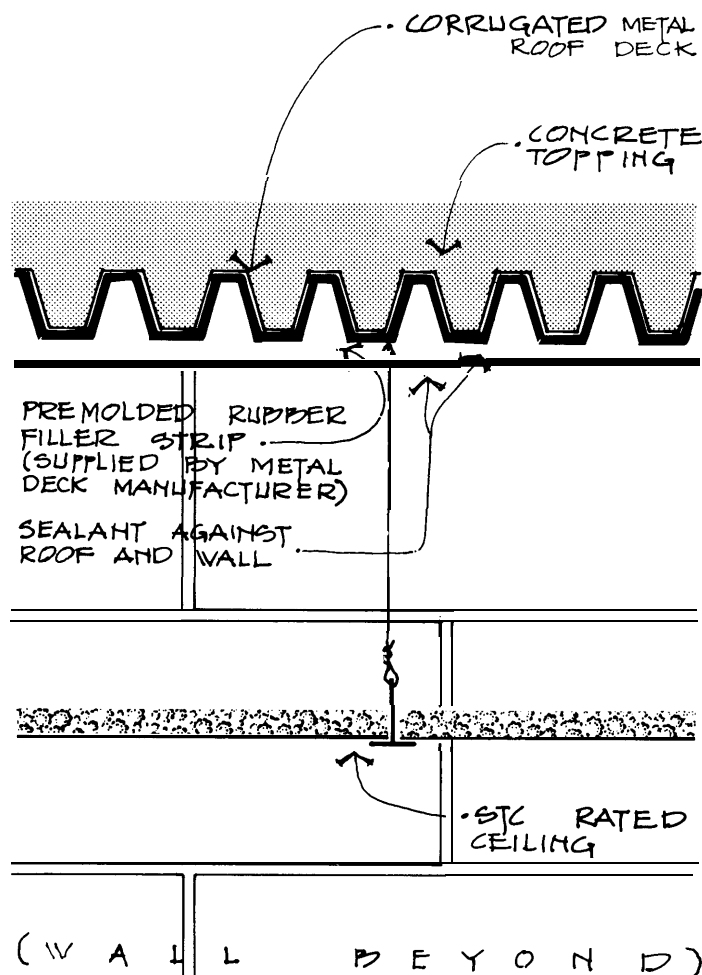


A. Wall running in same direction as deck corrugations

Figure 5-6. Joints Between Masonry Walls and Metal Roof Decks

Metal roof decks are unsuitable for use in Band Facilities, for several reasons. They are lightweight, stiff, and continuous for long distances, so they will carry vibrations from one room to many others. The corrugations of the decking make it extremely difficult to seal the wall/roof joint. The most effective modification to metal roof decks is regular weight concrete topping, to add mass and dampen vibrations.

If metal decking with concrete is used over Individual Prac-



B. Wall running across deck corrugations

tice Rooms (see Figures 5-6A and B), it should be shielded from the room with an STC-rated (STC 35-44) suspended ceiling. Careful attention must be paid to the joint between ceiling and wall, as the wall/roof joint, although it must be sealed, will be a more difficult problem. In the illustration in Figure 5-6A, fiberglass insulation is stuffed in the joint between the wall and metal deck, and sealant is run along the edges.

Figure 5-6B shows a concrete block wall running across the roof corrugations. A premolded rubber filler strip, supplied by the metal deck manufacturer, is set in a bed of sealant on the wall, and the joint between the filler and the roof is also sealed.

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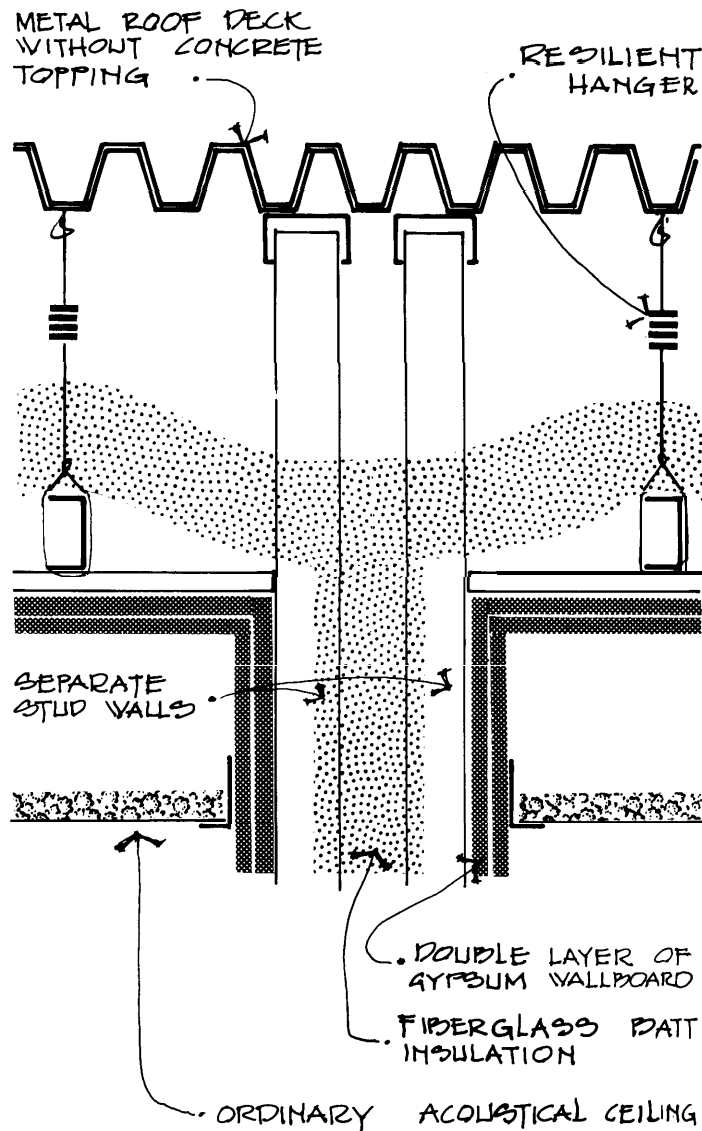


Figure 5-7. Isolating Music Rooms Under A Metal Roof Deck Without Concrete Topping

Metal deck without concrete (as in Figure 5-7) is a poor choice. If there is no alternative, install a double-layer resiliently hung gypsum board ceiling (plus some additional ceiling to provide absorption, as discussed in Paragraph 5-4, on Room Acoustics). Batt insulation lays over the gypsum ceiling which is suspended on resilient hangers.

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The joint between the walls and roof is critical to sound-proofing between rooms. Figure 5-5 shows single-thickness masonry walls joined to a concrete or concrete plank roof, and Figure 5-6 to a lightweight roof.

Any interior windows in these rooms should be double glazed with widely spaced panes. Small windows (less than

1 sq. ft.) may be single-glazed. No doors or windows should be located in the party walls between rooms. Doors can be solid core wood or fiber-packed hollow metal, with good seals along all sides including the threshold. Special acoustical doors normally are not warranted for practice rooms.

Table 5-2 Suggested Minimum Wall Separation Constructions

	INDIVIDUAL PRACTICE	SMALL GROUP PRACTICE	LARGE GROUP PRACTICE	MAIN REHEARSAL	AUDIO/ CONTROL
INDIVIDUAL PRACTICE	2	3	3	3	3
SMALL GROUP PRACTICE	3	3	3	4	3
LARGE GROUP PRACTICE	3	3	/	4	3
MAIN REHEARSAL	3	4	4	/	3
AUDIO CONTROL	3	3	3	3	/
OFFICES AND OTHER	2	3	3	3	2
TOILETS	2	2	2	3	3
CORRIDORS	1	1	1	1	1

1. Hollow Concrete Block.
2. Solid or Sand Filled Concrete Block, or Concrete.
3. As 2 Above, Plus Resiliently Attached Gypsum Wall Board Skins (depending on the required performance and on the construction details, the resiliently furred skins may be required on one or both sides of the block).
4. Tieless Double Masonry.

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B. Small Group Practice Rooms

Small Group Practice Rooms, 300 to 350 square feet in area, have a Noise Criterion of 30, and sound levels in the room may reach 95 dB. Thus, if adjacent, noise should be reduced by about 65 dB, requiring barriers rated STC 65. Again, this is a reasonable-not ultimate-goal. Non-adjacent location is advisable.

The isolation techniques described for the Individual Practice Rooms generally apply, but with more emphasis on superior performance. Solid masonry walls should be upgraded with resiliently attached gypsum board or plaster walls (always backed with acoustical batt insulation), as illustrated in Figure 5-8.

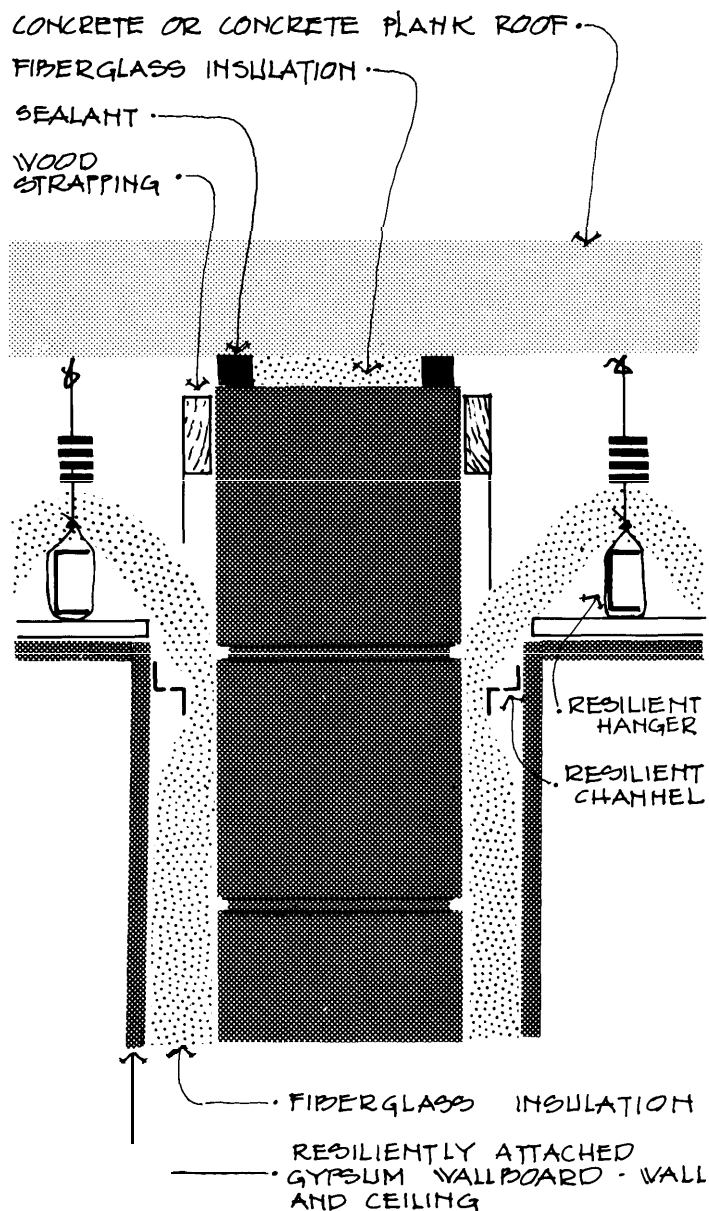


Figure 5-8. Resiliently Attached Gypsum Wallboard Skins to Improve Performance of Single Masonry Walls

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Wall skins (Figure 5-9A) should be joined continuously with the ceiling skin, which should be suspended on resilient hangers (illustrated in Figure 5-9B), with acoustical batts laid on top. Note that another ceiling is necessary below this isolating ceiling, for room acoustics purposes. This con-

struction is always necessary in the case of metal roof decks. But, under a concrete or concrete plank roof, an STC rated acoustical ceiling can combine attenuation with absorption.

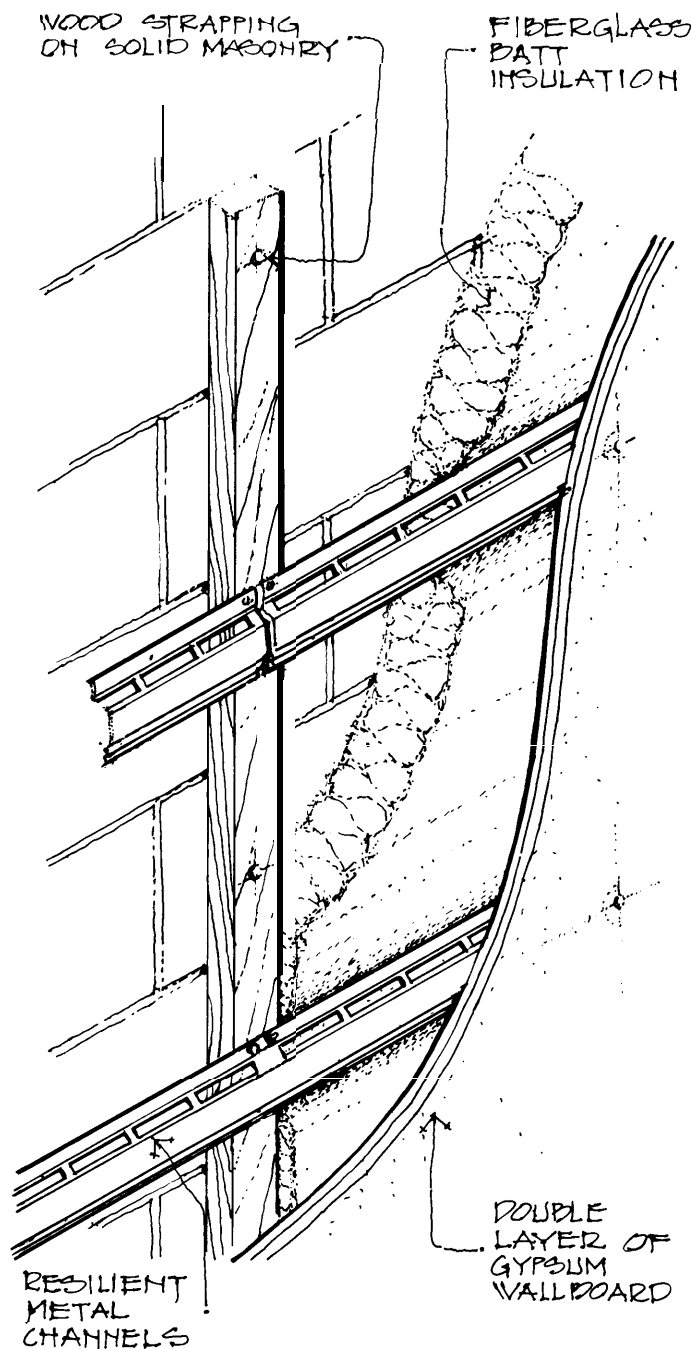
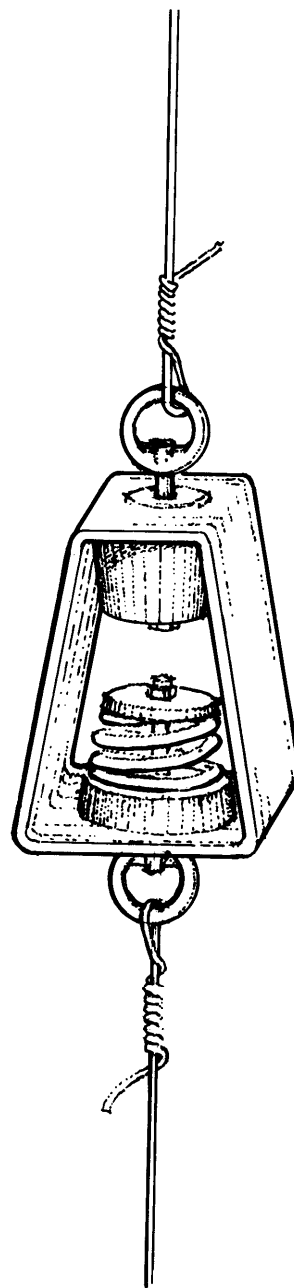


Figure 5-9. Resiliently Furred Construction
A. Cutaway of wall construction



B. Resilient ceiling hanger

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Doors to these rooms could be either good quality solid core wood or packed metal doors with acoustical seals or specially manufactured sound control doors. Double glaze win-

dows to interior spaces (corridors and lobbies), with 2 to 3 inches between panes. Line the space between panes at jamb, sill and head with an inch of fiberglass.

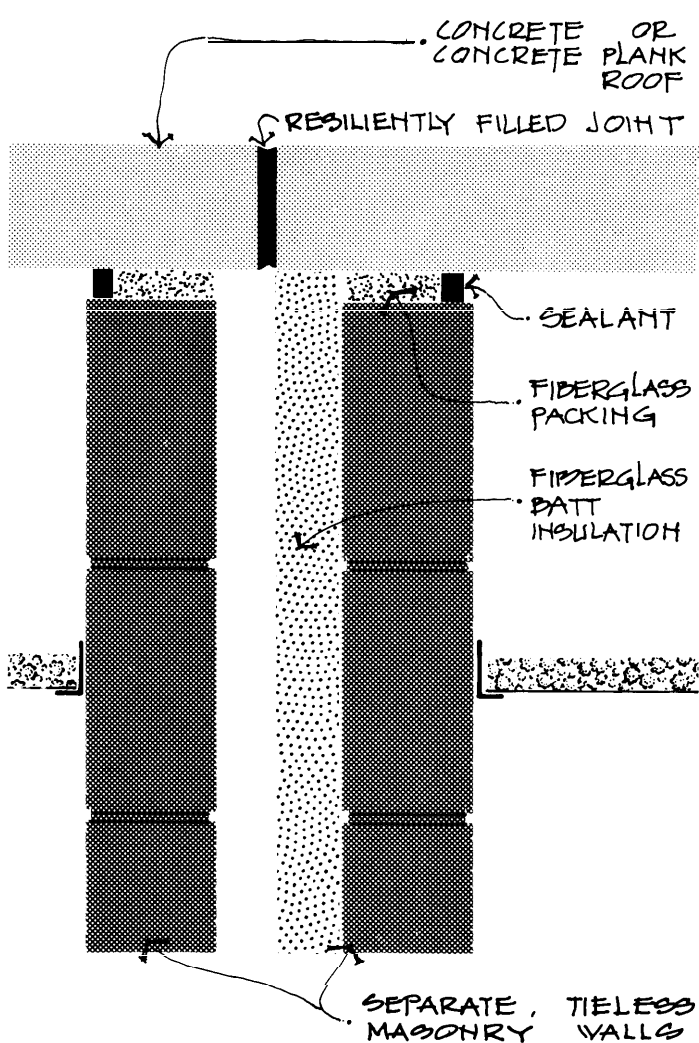
Table 5-3 Recommended Ceiling Treatment

ROOM TYPES	ROOF CONSTRUCTION				
	CONCRETE ROOF	PLANK ROOF	PLANK ROOF WITH RESILIENT JOINTS AT RESILIENT WALL SEPARATIONS	METAL ROOF WITH CONCRETE TOPPING	METAL ROOF WITHOUT CONCRETE TOPPING
INDIVIDUAL PRACTICE	1	1	1,3	5	2,4
SMALL GROUP PRACTICE	5	5	1,3	7	2,4
LARGE GROUP PRACTICE	5	5	1,3	7	N.R.R
MAIN REHEARSAL*	3,1	1,3	3,1	1,3	5

This table shows recommended ceiling treatments for different room types, depending on type of roof construction. It indicates the most cost effective combination; other ceilings are possible if they meet criteria discussed in the text.

1. Ordinary acoustic tile suspended (also provides acoustic absorption).
 2. Ordinary acoustic tile suspended, under resiliently hung gypsum wall board ceiling.
 3. Absorbent panels (fiberglass, etc.) - (provides no isolation).
 4. Absorbent panels under resiliently hung gypsum wall board ceiling.
 5. STC rated acoustic tile (35-44 STC) (provides absorption and isolation).
 6. STC rated acoustic tile (35-44 STC), plus gypsum wall board ceiling.
 7. Absorbent panels below gypsum wall board ceiling.
- N.R. not recommended

*This assumes the roof of the Main Rehearsal Room is not continuous with the roofs of other music spaces. If otherwise, higher quality constructions are required.



C. Main Rehearsal Room, Large Group Practice Room and Control/Recording Booth

The recommended background noise level in these spaces is NC-25, though up to NC-30 may be acceptable in the Large Group Practice Room. Isolation requirements are more stringent for these uses than for those already discussed. These spaces are all usually placed in close proximity, so wall constructions on the order of STC 75 may be needed. This much isolation is quite difficult to achieve. In practice, placing the Control Booth between the Main Rehearsal and Large Group Practice is best. The booth will then form a buffer between the active music rooms (the isolation between either room and the booth is in any case compromised by the window).

Solid masonry, with resiliently furred gypsum-board skins on each music room wall, will be adequate for wall construction between these spaces (as already discussed in Figure 5-8). Such walls do not achieve the best performance, but are compatible with the required windows. (The windows are still weaker than the walls, but their small area tends to transmit less sound than the larger area of the walls.)

Where Large Group Practice or Main Rehearsal Rooms are directly adjacent to each other or to other music rooms (see Figure 5-10), construction should be tieless double masonry walls with acoustical batt insulation between, with a concrete (preferable) or concrete plank roof. The insulation also aids in preventing inadvertent mortar bridges between the layers, which would compromise the isolation. The concrete roof should be discontinuous (or shielded by an STC-rated ceiling) to avoid flanking.

Figure 5-10. Tieless Double Masonry Wall

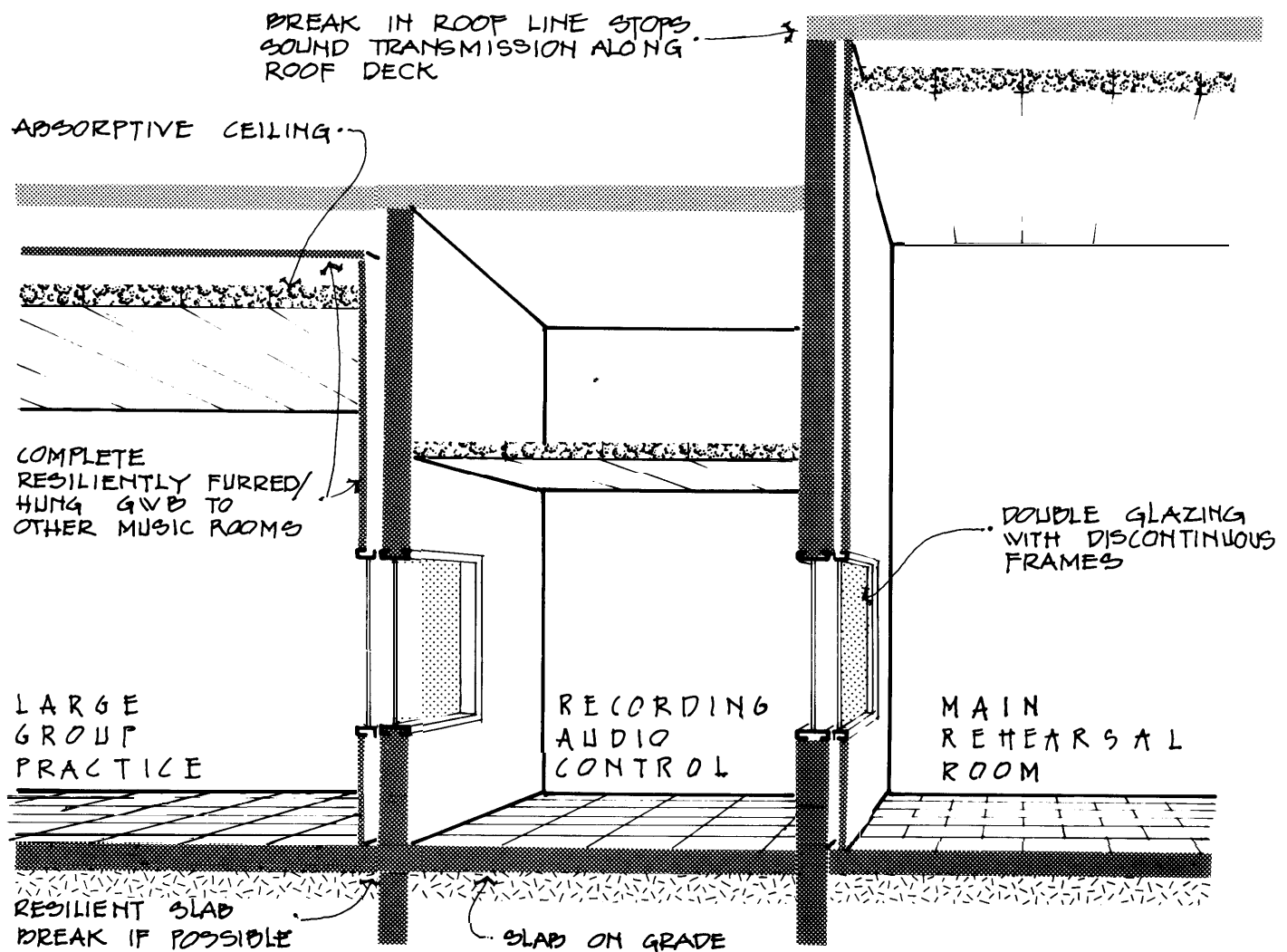


Figure 5-11. Section Through A Typical Large Group Practice, Recording, and Main Rehearsal Room Complex

For improved performance, the concrete slab-on-grade could also have a resilient joint in line with either the resiliently attached wall, or between the two layers of a double masonry wall, depending on the condition.

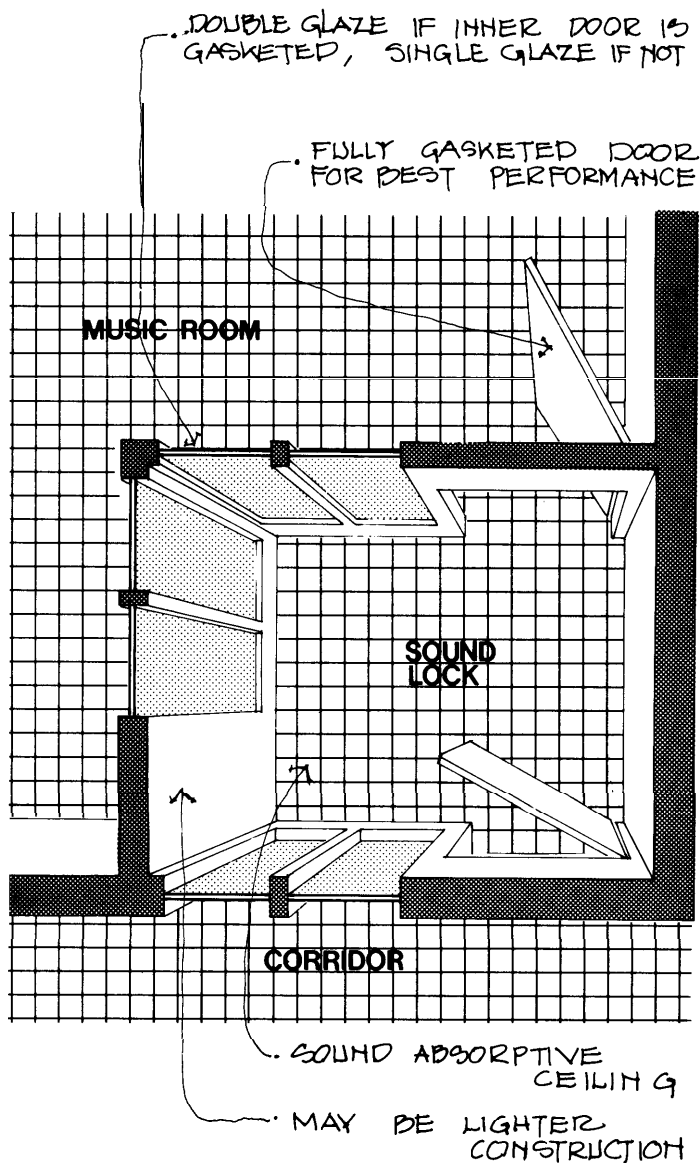
The roof deck over these major spaces should be broken—with a change in roof plane or a parapet—at music room separations, so the deck doesn't carry vibrations from one music room to another. If the roof slab is noncontinuous, suspend a resiliently hung gypsum board ceiling in one of the rooms, or provide both rooms with normally hung STC-rated acoustical ceilings.

Figure 5-11 illustrates a typical Large Group Practice/Recording/Main Rehearsal Room complex, similar to those shown in the illustrative designs for 45 and 64 person band new construction (see Chapter 6). In this case, construction is of single, solid masonry walls, with resiliently attached gypsum board wall skins. Since the Large Group Practice and Recording Rooms share a common pre-cast concrete roof deck, the ceiling of the Large Group Practice is shielded with a resiliently hung gypsum board ceiling, continuous with the gypsum board wall skin. Since the roof over the Main Rehearsal Room is not continuous

with the other rooms, isolation required of the ceiling is minimal, and can be provided by an ordinary suspended acoustical ceiling. Wall isolation is still required, in this case forming a barrier sealed to the roof. To further increase isolation, a slab break between rooms is recommended. It is shown here only at the Main Rehearsal Room wall. Absorptive ceilings are required in all these spaces, suspended below the isolation construction.

Metal roof decks without concrete topping are absolutely unacceptable in this application. Decks with topping must also be shielded with a resiliently hung gypsum board ceiling (similar to Figure 5-8). An alternative to the gypsum board ceiling is construction of a resilient joint in the roof in line with the room separation (resilient or double wall) below.

Doors to these major music spaces—especially to the Main Rehearsal Room—should be the best in the building. Sound locks (illustrated in the door discussion, Figure 5-12) are preferred. Even with these, one of the two doors (usually the inner) might be gasketed. If sound locks are not possible, use special acoustical doors, rated at least STC 40.



D. Doors

Doors are always the nemesis of sound control planning, since they depend on the performance of seals that are in constant operation and thus susceptible to deterioration. A properly constructed wall will always perform, but doors depend on frequent adjustment or maintenance of the seals.

Doors are rated by Sound Transmission Class (STC) as are other constructions, but STCs achievable for doors are lower than for similarly complex walls etc., and the best acoustical doors are expensive. Manufacturers recommend that door STCs be lower than those for walls. Within reason, this is correct, because doors generally constitute a small portion of the wall. A range of doors recommended for band facilities is described below. For reference, a wood, solid core, ungasketed door rates about STC 20 (see also Table 5-1).

- **STC 30 +** —minimum for Individual Practice Rooms; also for sound locks (inner door). To achieve this, use solid wood or fiber-filled metal door, with full gasketing along all sides including sill and, for double-leaf doors, where the two leaves meet. Gaskets of various configurations are available from most weatherstripping manufacturers, but they must be compliant (neoprene, vinyl, etc.) to make an airtight seal. Hollow metal frames are grouted or packed with insulation. Joints between frame and wall must be well sealed.
- **STC 35 +** —preferred for Individual Practice Rooms and sound locks; minimum for the larger music rooms. Use either non-proprietary doors as described above, but with the least possible seals, very well installed and adjusted, or proprietary acoustical doors rated at least STC 35. The latter comprise a complete assembly including door, frame and seals.
- **STC 40 +** —preferred for all critical band facility applications, especially for Main Rehearsal and Group Practice Rooms, if sound locks cannot be provided. Use proprietary acoustical doors rated at least STC 40. Good installation approaching or exceeding STC 50 are thick, heavy, and very expensive. They may be required in some cases, but are best avoided by appropriate planning.

Sound locks, shown in figure 5-12, consist of a vestibule and two doors, and are much more effective than a single door. Only one of the doors need be gasketed, and even this is not always essential. Although they take up additional floor space, sound locks are highly recommended for the larger music rooms. They offer good performance without depending on perfect gasketing. With one or both doors gasketed, their performance could well match that of the surrounding walls. The inside door, in the sound lock illustrated, is fully gasketed for best performance. The glazing should be doubled if the inside door is gasketed, but may be single if not. The vestibule itself should have an absorptive ceiling. The vestibule enclosure may be lighter construction than the heavy outside wall.

Figure 5-12. Sound Lock—Overhead Plan View

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Double doors, into Group Practice and Main Rehearsal Rooms (Figure 5-13), should have one active and one inactive leaf. The inactive leaf would be fixed in place with floor and head bolts, until needed to move a grand piano or similarly large instrument. An astragal (overlap strip where the doors meet) must be attached to one of the doors, to compress a sound seal. Cam operated drop seals (discussed later) should be used in these cases, as thresholds would knock the piano out of tune when it is rolled in and out. The active leaf in a double door should be a large door (3'-4" or 3'-6"), so musicians carrying tubas or other large instruments can pass through easily. The inactive leaf can be smaller so the total opening available through both leaves is at least 6'-0".

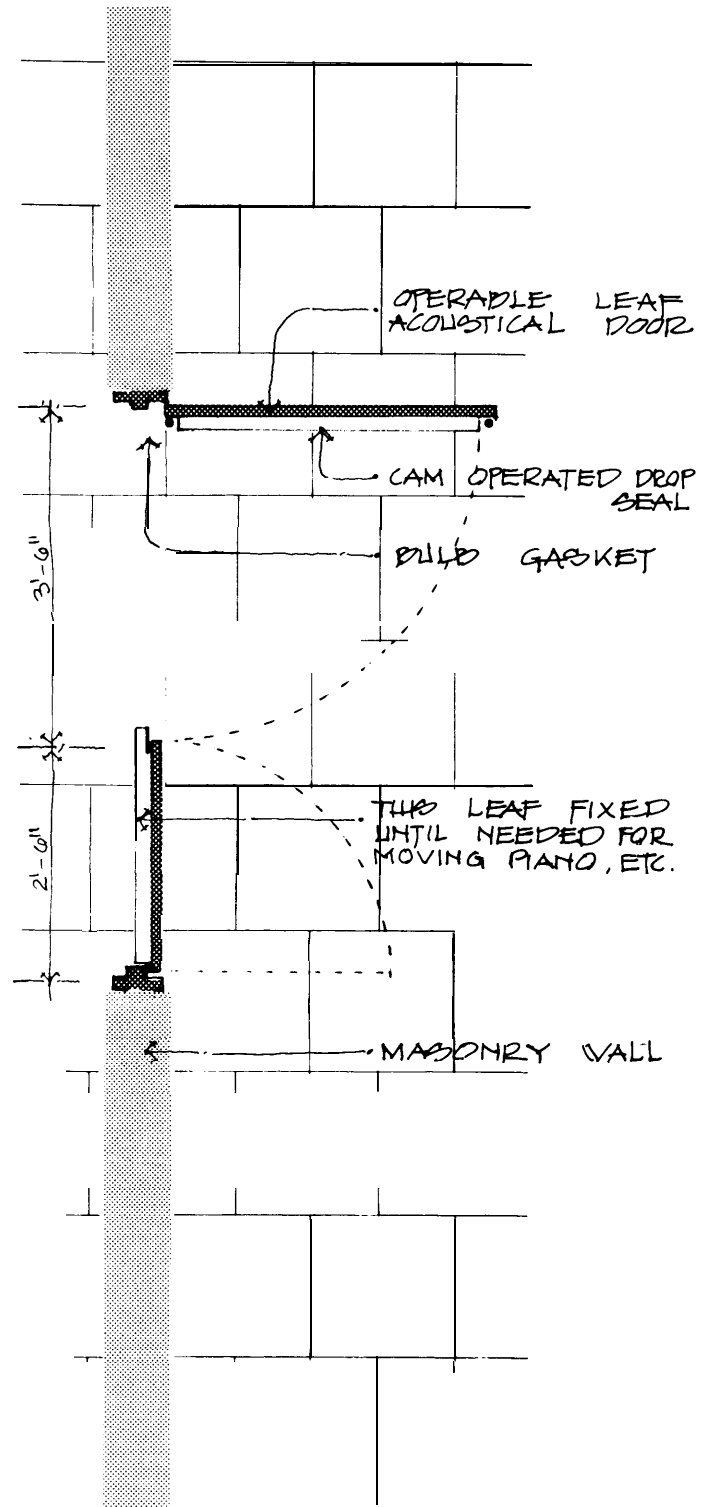


Figure 5-13. Plan of Music Room Double Doors

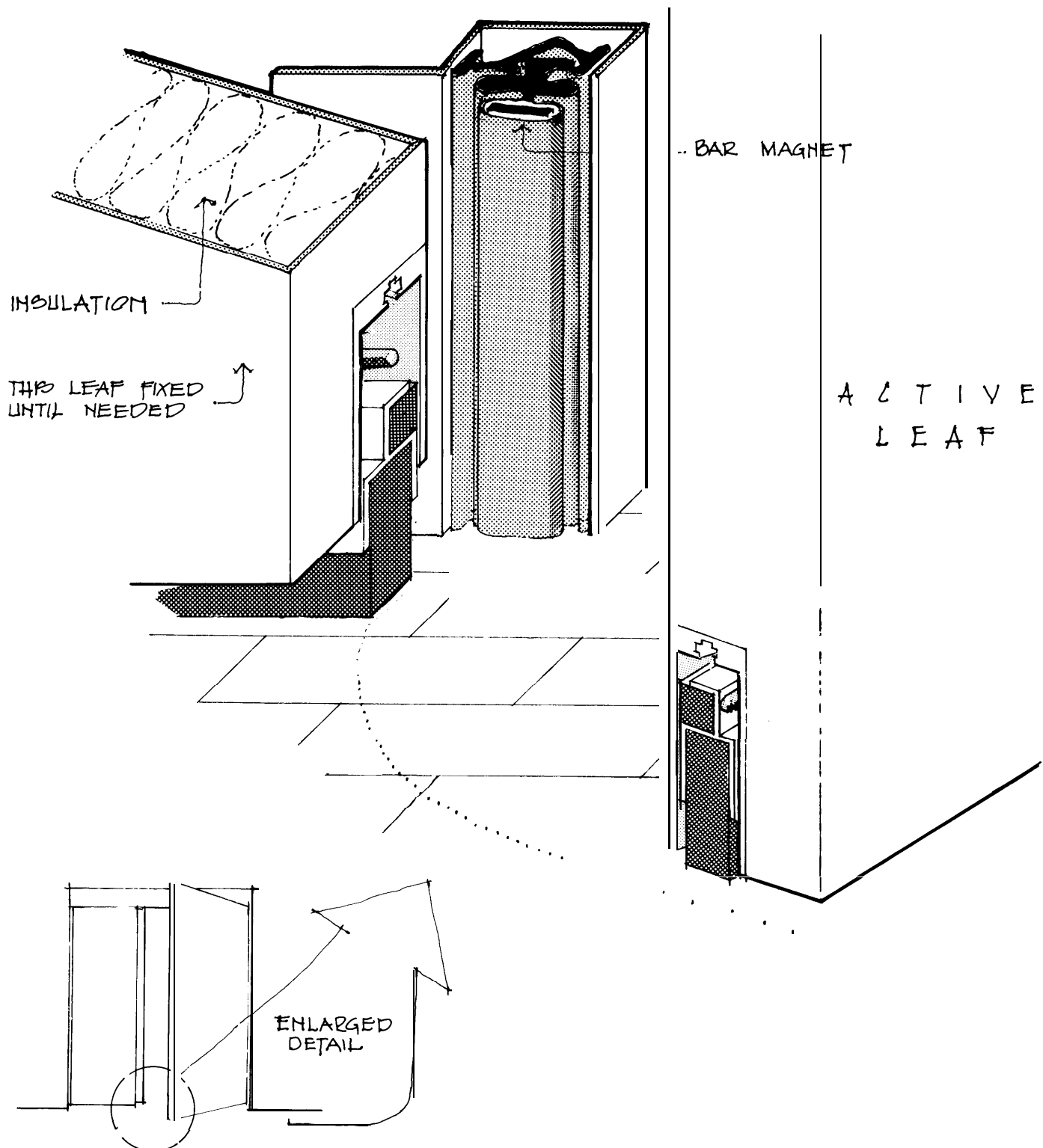
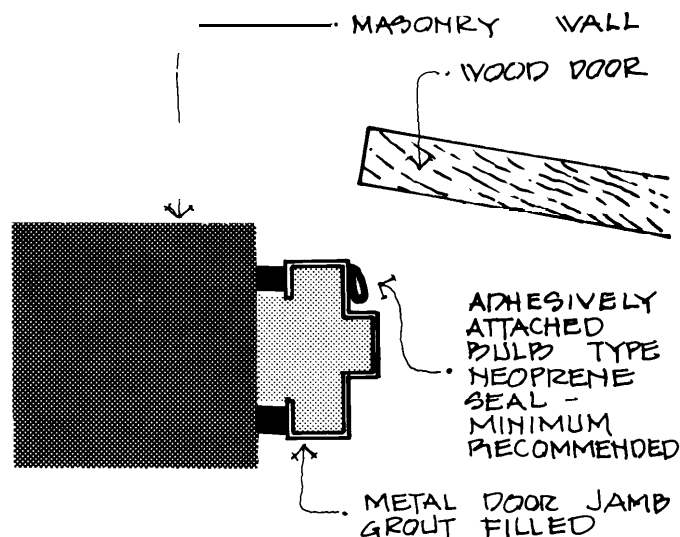


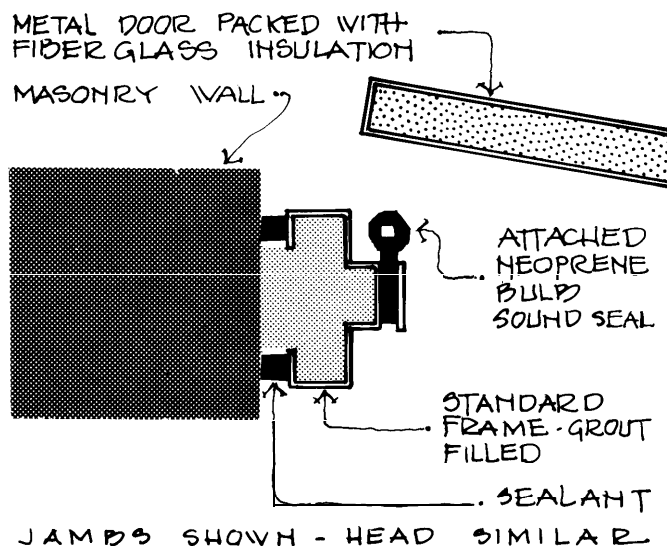
Figure 5-14. Double Door Meeting at Astragal

Figure 5-14 depicts the details where the doors meet. The inactive leaf is fixed with a floor bolt until needed. The drop seal is shown down, sealing the door bottom. An astragal with a magnetic seal (a bar magnet inside a flexi-

ble vinyl gasket) will grip the active leaf when it closes. The active leaf, since it is shown open, has the drop seal raised.



A. Adhesively attached bulbtype neoprene strip



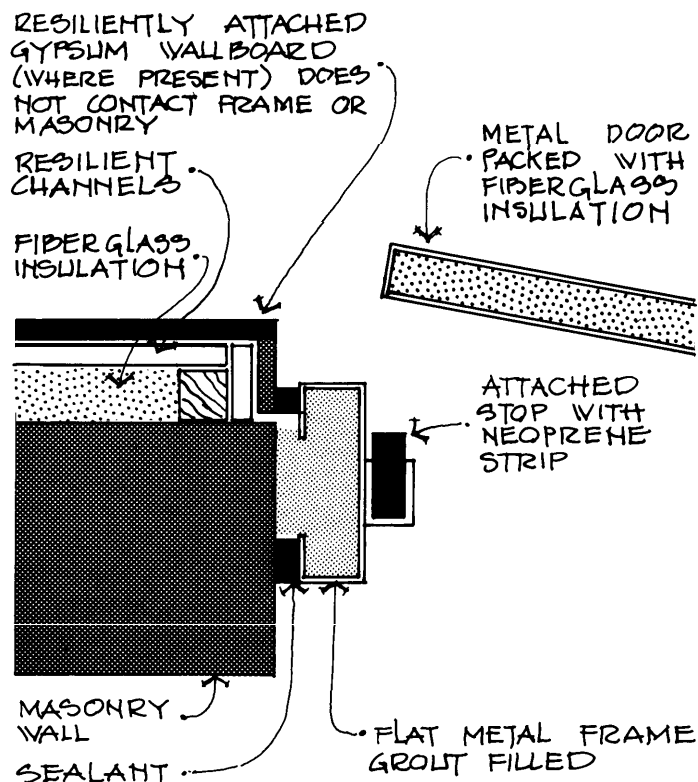
B. Attached neoprene bulb seal

Small fixed windows in acoustical doors (up to one foot square) may be single-glazed (one pane of glass). For larger windows in or next to acoustical doors the considerations from Section E, Windows, should be applied.

Door frames should be either grout-filled or packed with fiberglass, and sealed to the wall. Figure 5-15 illustrates several types of head and jamb gaskets. Jambs are shown, heads are similar. Example A has an adhesively attached bulbtype neoprene strip, recommended for minimum conditions such as individual practice rooms, and compatible with a solid wood door in a grout-filled hollow metal frame. The gap between frame and masonry is sealed with a good quality permanently flexible sealant.

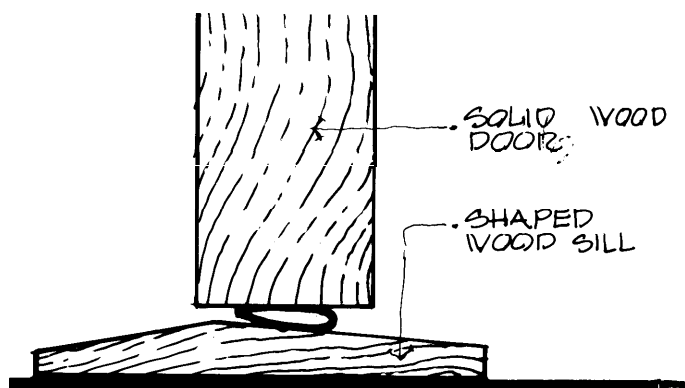
An improved quality sound seal is shown in B. The seal is an attached neoprene bulb seal held in place with a metal strip. The door is hollow metal, packed with fiberglass insulation.

In further improvements, Illustration C, the frame is installed in a wall consisting of both masonry and gypsum drywall, which is resiliently attached to furring channels on the masonry. Sealant eliminates any rigid connection between grout-filled frame and the resilient gypsum. The stop is an attached metal channel with a projecting neoprene strip, applied to a flat jamb.



C. Resiliently attached to furring channels on the masonry

Figure 5-15. Acoustical Door Frames and Seals

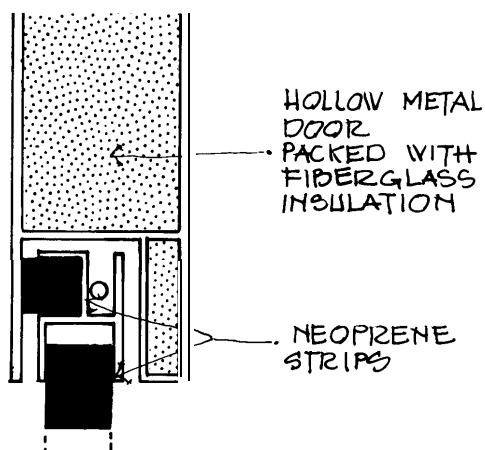


A. Raised threshold

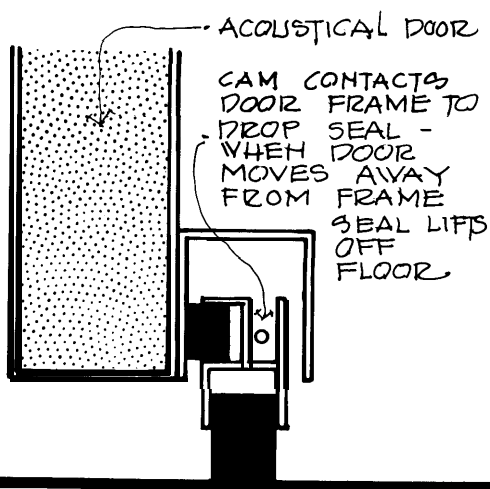
A raised threshold is most effective for stopping noise, but it makes moving heavy musical instruments and sound equipment difficult, and it may be a danger when a large number of people are using the door in a short time. Raised threshold seals (Figure 5-16A) are effective for individual Practice Rooms. The wood door shown compresses a neoprene bulb sound seal against the wood threshold.

Cam-operated drop seals (5-16 B and C) are recommended for larger music rooms. The cam is a rod through the door, which is pushed by the frame when the door closes, and lowers the seal. When the door opens, the cam is released and the seal raises by springs. The path over the bottom seal is also closed by a seal that slides against the door side. The moving bar is metal, with neoprene or felt inserts. Figure 5-16 C shows a cam-operated drop seal attached to the door, rather than integral as in B. It is shown in closed position.

Door closers must be strong enough to close the doors against the resistance offered by all types of compression seals. All seals should be located in one plane, to eliminate leaks at corners where otherwise adjacent seals may not meet.



B. Cam operated drop seal built into door



C. Surface mounted cam operated drop seal

Figure 5-16. Acoustical Door Bottom Seals

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E. Windows

Except on unusually noisy sites (e.g., near airfields), there is no need for special exterior glazing. Even where such need exists, remember that an open window (for natural ventilation) provides zero sound attenuation.

The best acoustical improvement that can be made to a window is double glazing, with the largest possible space between the two panes of glass—as much as the wall thickness permits, but no less than 2 or 3 inches. The two panes must not be rigidly connected to each other. Either set the glass in neoprene gaskets, or, if the window is installed in a double wall, split the frame. The frame area between the panes should be absorptive. Performance of the two panes is improved if they are of different thicknesses, so that sympathetic vibrations are not transmitted from one to the other.

Figure 5-17A shows a hollow metal window frame assembly in a masonry wall. A metal frame packed with fiberglass is attached to the masonry, and sealed along its edges. Other metal "Z" angles are assembled to form a pocket for acoustical absorption (more fiberglass behind a cloth screen); and to form channels to hold the glass in neoprene gaskets.

The construction in Figure 5-17B deals with the problem of a double wall, resiliently attached gypsum wallboard on masonry. This frame is shown in wood, but it can be built in metal as well. Sealant keeps the frame from firm attachment to the resilient wall (the only structural attachment being to the masonry). Wood stops form similar conditions to that described above.

Windows are no match for the isolation provided by solid walls. Interior windows should be installed only where absolutely necessary, either for supervision, checking on occupancy or relief of claustrophobic conditions, or to allow visitors in the Lobby to view functions in the music rooms. Windows smaller than 1 foot square may be single glass, whether in walls or doors.

The most critical window installation is between the Recording/Audio Control Booth and the Main Rehearsal and Large Group Practice Rooms. Split frames and double glazing are recommended. One pane might be laminated acoustical glass; but, in general, ordinary plate glass of 1/4" to 1/2" is acceptable in this building type.

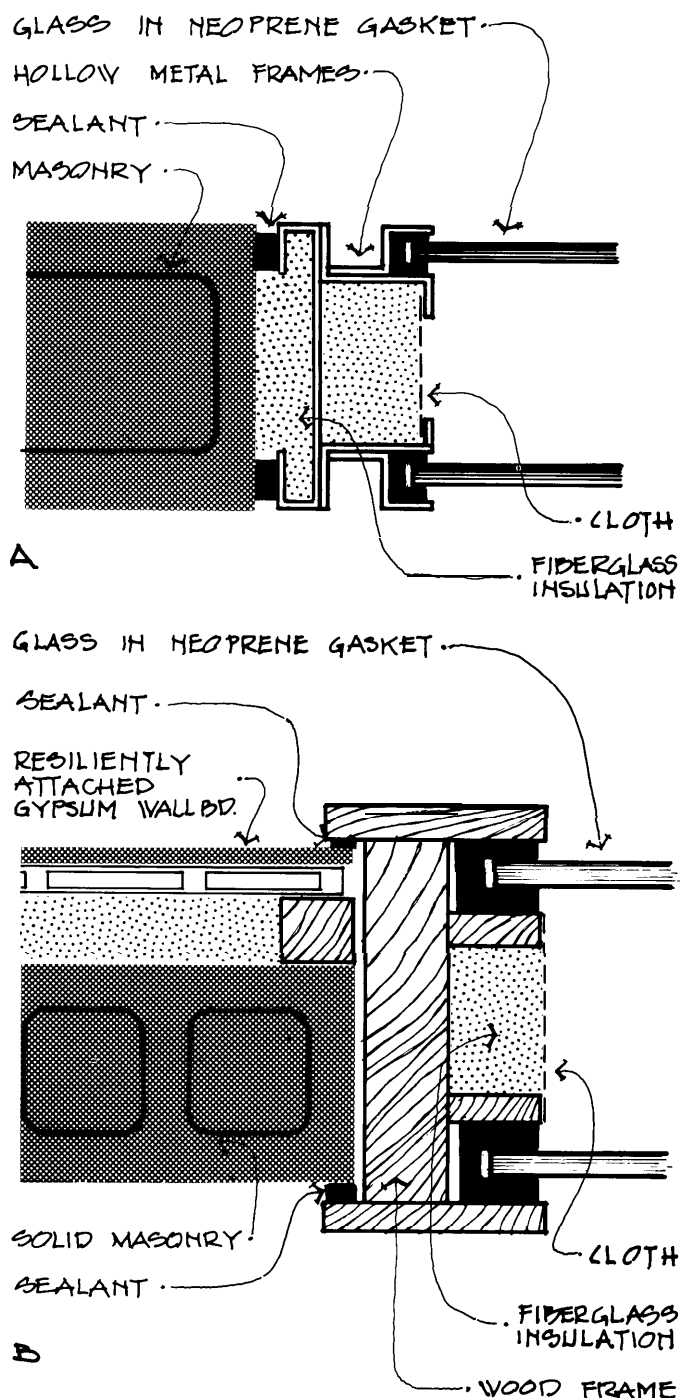


Figure 5-17. Window Frame Details - Alternative Methods of Constructing Double-Glazed Windows for Sound Isolation

F. Lighting and Electrical Systems

Electrical systems must be designed to eliminate noise from the fixtures themselves, to prevent components and conduits from transmitting sound from one room to another, and to avoid air leaks incidental to installation.

Ballasts for fluorescent lighting in any music room used for critical recordings should be installed remote from the room, to eliminate noise. In Individual Practice Rooms, use A-rated ballasts, which may be located at the fixture. Any clocks in music rooms should be silent-type.

To avoid conduits becoming conductors of sound, slack sections of flexible conduit should be used where they cross music room walls which have resilient gypsum wall board skins. Avoid running power distribution conduits above music spaces, or across their ceiling plenums. Try to avoid wiring within isolation walls, as the solidity of the construction will be compromised. Wall outlets should never be back to back.

Use of surface mounted fixtures will avoid cutting large holes in isolation walls and ceilings, although lighting may be recessed in the absorbent ceilings that are not part of isolation. (Sound-rated suspended ceilings are designed for integral lighting without compromising their performance). If outlet boxes and switches must be recessed into sound-

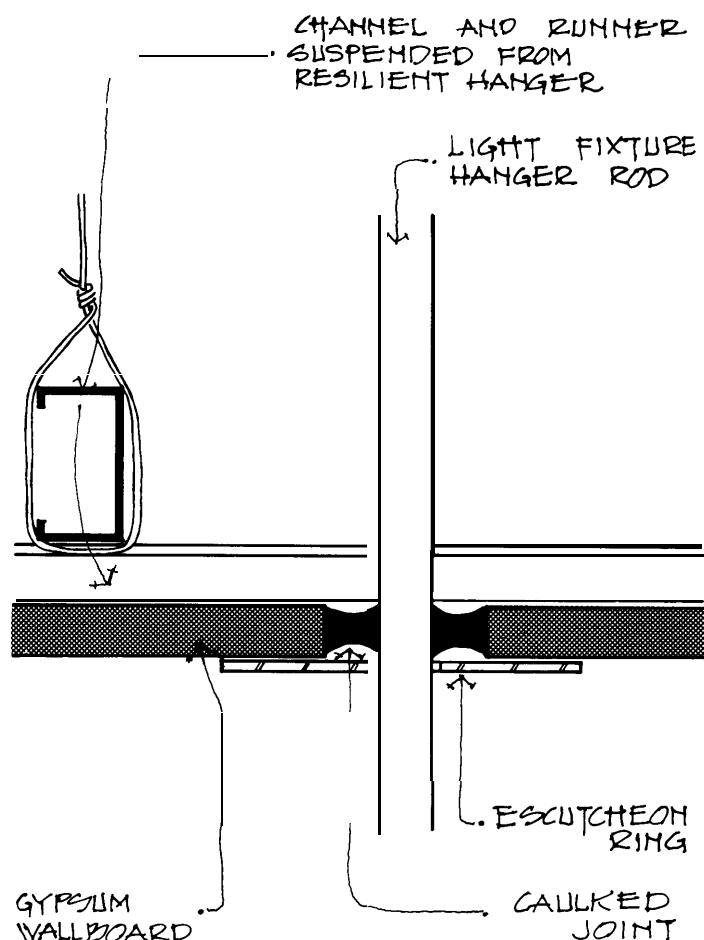


Figure 5-18. Light Fixture Hanger Rod Passing Through a Resilient Ceiling

isolating barriers, they should be well-sealed (to maintain airtightness) and, if the barrier is resiliently attached, the box or switch must not compromise the resiliency. Figure 5-18 illustrates a light fixture hanger passing through a resiliently hung ceiling. The caulked joint around the hanger rod not only seals the opening but also avoids rigid contact between the resiliently suspended ceiling and the rod. The resilient ceiling hanger is also shown. An escutcheon is optional to hide the joint.

5-3 Noise Control and Mechanical Systems

Background noise in buildings is primarily produced by outdoor traffic and the building's own mechanical systems. Traffic noise is seldom a problem in closed, air-conditioned buildings, unless they are located along busy streets or highways, which is not recommended (see 2-5.A.3).

The mechanical systems must be engineered for quiet operation, but preferably so that the noise level is not much below the applicable NC criteria (see Table 3-1). Bland background noise, at modest levels, helps mask other intrusive sounds, with which even the best sound-isolating barriers cannot cope. The principal sources of this mechanical system background noise are: the fans that circulate air; the ducts, including volume control boxes, that distribute the air; and the diffusers and grilles through which air enters and leaves the room. Each must be considered if correct background noise levels are to be achieved.

A. Fan Noise. Fan noise—often a low-frequency rumble—travels equally with and against the airflow. Consequently, supply and return air systems merit equal consideration. The initial noise level (at the fan) depends on factors such as fan type, capacity (cfm), and static pressure. In general, the larger the fan, the noisier it is. The noise is carried by the ducts which, unless treated, offer very little attenuation. The only acoustically effective treatments are internal glass fiber lining (not less than 1" thick) and silencers that can be inserted in the ducts.

B. Duct Noise. Noise generated in the ducts is due to turbulence caused by sudden velocity changes, sharp turns, and generally by high air speeds. It tends to be strongest in the middle frequencies. The best solution is to minimize duct noise by careful design—by promoting smooth airflow at moderate velocities—and by inserting adequate lengths of acoustically-lined duct between points of turbulence (such as volume control boxes) and the room.

In general, ducts between fans and the music rooms they serve should be of generous length and lined with 1" fiberglass. In addition, if ducts are of insufficient length, manufactured duct-silencers should be inserted. Common ducts serving several music rooms should be long, with some 90° bends, and acoustically lined. In buildings served by high-pressure, high-velocity systems, pressure and velocity must be reduced outside the music rooms, i.e. before ducts penetrate the rooms' sound-isolating constructions.

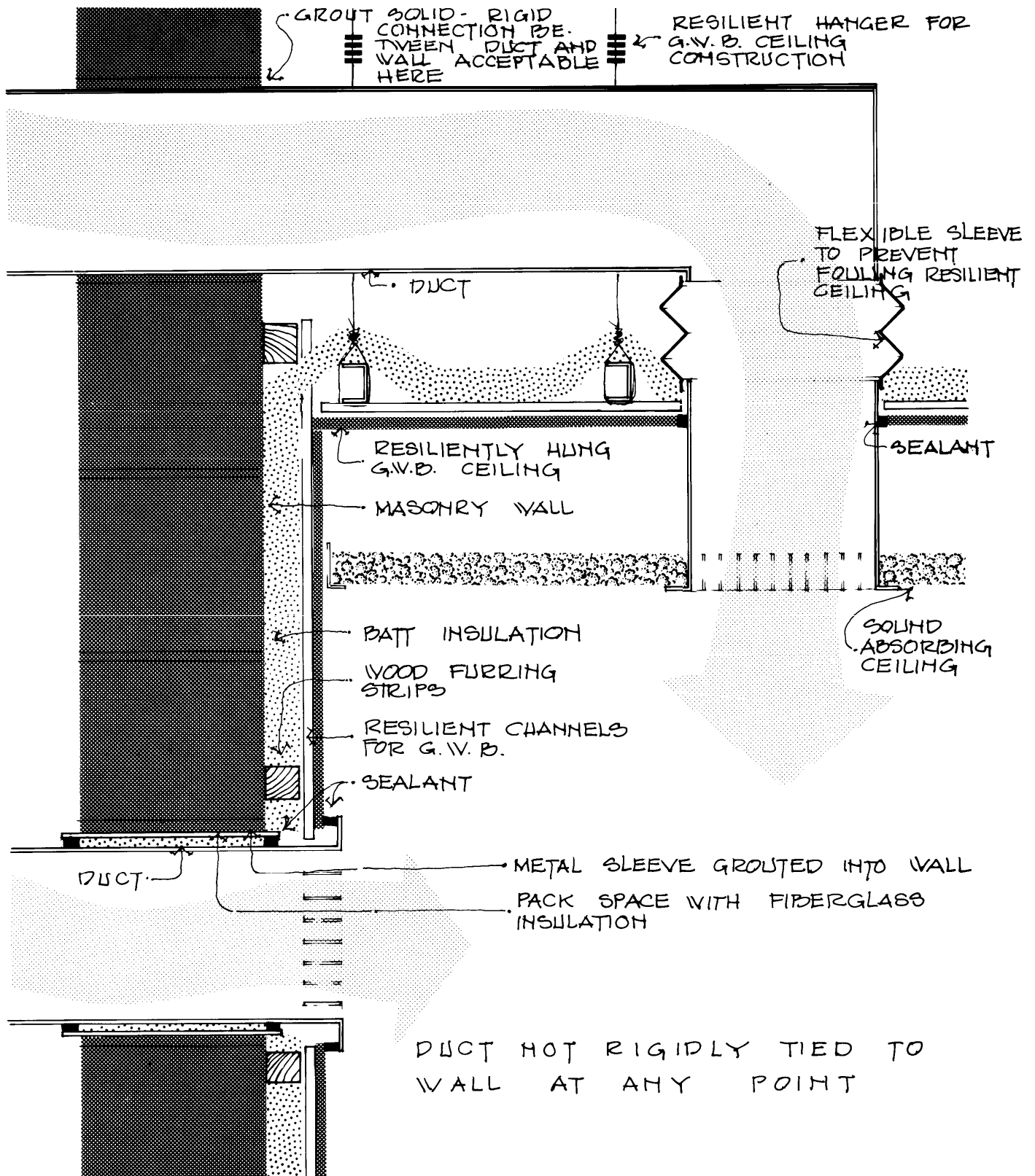


Figure 5-19. Duct Penetrations in Sound-Isolating Construction

The air distribution systems should be so designed that at no point in the building, in any duct, does the airflow exceed 1500-2000 feet per minute.

Airflow velocities in the terminal necks of ducts where they connect to diffusers or grilles should not exceed 370 fpm for NC-25, 450 fpm for NC-30, 550 fpm for NC-35, and 675 fpm for NC-40.

C. Diffuser Noise. Noise at the diffusers and grilles—typically a mid-to high-frequency hiss—also is caused by turbulence as air is forced through restricted openings. It is exceedingly velocity-dependent: a doubling of airflow through a given device will increase the noise level by 15 to 20 decibels. The only acoustically safe approach is to use oversized diffusers and grilles with large free area, without integral volume control dampers, straighteners, or equalizing grids. Diffusers and grilles serving music rooms should not incorporate volume control dampers. If required, these are best located at the branch duct takeoffs, because their noise will then be attenuated by the acoustically lined ducts.

D. Existing Systems. Mechanical systems should always be designed to meet the recommended criteria. If existing systems are involved, their noise levels should be measured and the feasibility of reducing any excess noise should be investigated.

E. Equipment Location. All major equipment should be located remote from the active music rooms. Fans, pumps, compressors, etc. are best located on-grade, where they can be more easily vibration-isolated. Mid-span locations on long-span structures are unacceptable. All rotating, reciprocating, and vibrating equipment must be resiliently supported or hung. All their connections to the building structure must be resilient; and ample static deflection—up to several inches in the most critical cases—should be specified.

F. Penetrations of Sound-Isolating Construction. Penetrations through sound-isolating walls and ceilings must be perfectly sealed. The annular openings around ducts and pipes should be either grouted solid or sealed with a non-hardening sealant (see Figure 5-19).

5-4 Room Acoustics

Achieving satisfactory room acoustics for practice and rehearsal is a complex matter. As discussed in 3-5.C, the concerns include loudness and reverberation control, clarity and communication among the members of an ensemble, and avoidance of certain unwanted effects. Adequacy in all these respects is difficult to define, since individual musicians and bandleaders have their own standards of reference, often based on past experience in rooms that may or may not have been to their liking. The following paragraphs describe the means of achieving results that should satisfy most users of the facility.

A. Absorptive Finishes

Absorptive finishes reduce reverberation as well as loudness. Most are porous (fibrous or cellular), allowing sound to enter the material, where its energy is converted into heat. Fiberglass board is an excellent example. To be effective, such materials must not be too thin—at least 1" —or they must be backed by an airspace of at least several inches. Some absorbers are not porous, but they are thin and free to vibrate in response to the sound. For example, thin wood paneling (or even furred gypsum board) vibrates and thus, by resonance, absorbs sound. However, resonant absorbers are much less efficient and their absorptivity is limited to the low frequencies.

Absorptivity is commonly given by the material's Noise Reduction Coefficient (NCR*). But like the STC (for isolation), it does not indicate low-frequency performance, which is of considerable interest in the design of band rooms. It can be used as a guide, but with this important qualification: every room should have at least one major surface that not only has a high NRC (0.60 or more), but also absorbs low-frequency sound. Most typically, this requirement is met by using a suspended (not glued-on) acoustic tile or lay-in ceiling. The low-frequency absorptivity, by resonance, of any furred wall is not enough. Low frequency absorption can also be provided by a large air space behind wall mounted panels, as in the corner treatment illustrated in Figure 5-20.

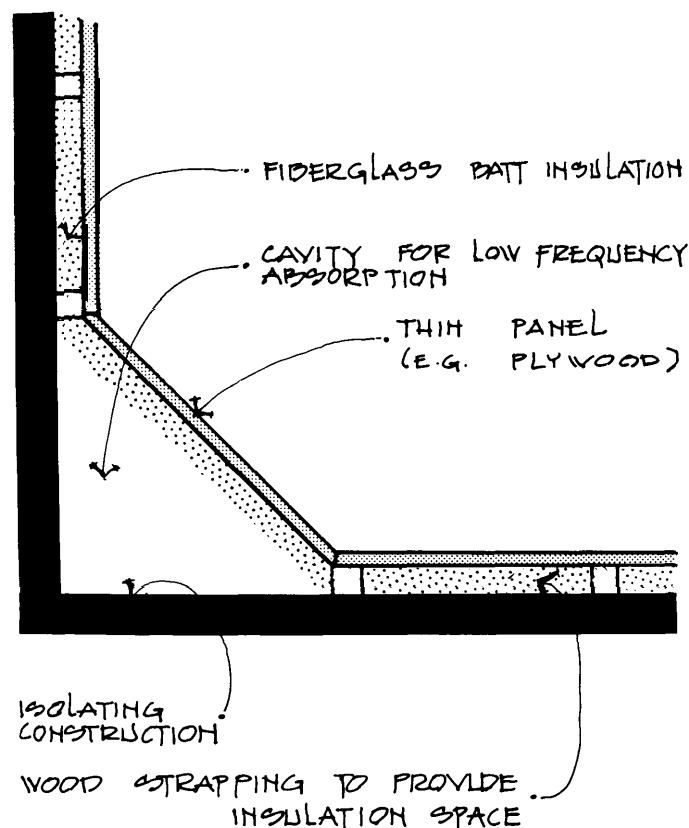


Figure 5-20. Diagonal Corner Construction for Low-Frequency Absorption

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Practical Approaches for Acoustic Construction

Typical NRC's of various finishes and treatments are given in Table 5-4. Specific materials suitable for music practice and rehearsal rooms are described below.

- Semi-rigid fiberglass board, 1" to 2" thick, covered by a sound-transparent material such as cloth, perforated vinyl or metal, or an open mesh or screen.
- A similar detail to the above, made of fiberglass batts, or if a dark finish is desired, of fiberglass duct liner board. (Batts are also very effective if placed behind fiberglass board, to increase the treatment's thickness to 3" or 4".)

*The Noise Reduction Coefficient (NRC) is the arithmetic average of a material's sound absorption coefficients in the octave bands centered at 250, 500, 1000 and 2000 Hertz, rounded off to the nearest multiple of 0.05.

- Wood-fiber panels such as "Tectum", backed by at least 1-1/2" batts, since such panels alone are not very efficient.
- Heavy—typically velour-curtains, draped to one-half to two-thirds their flat area, and held 6" or more off the wall. As noted earlier, the movability of such cur-

tains affords acoustical variability.

- A wide variety of acoustical ceilings, made of mineral fiber, fiberglass, as well as fiber-backed perforated metal. These should always be suspended at least a foot below the solid deck or ceiling, to enhance low-frequency absorptivity.

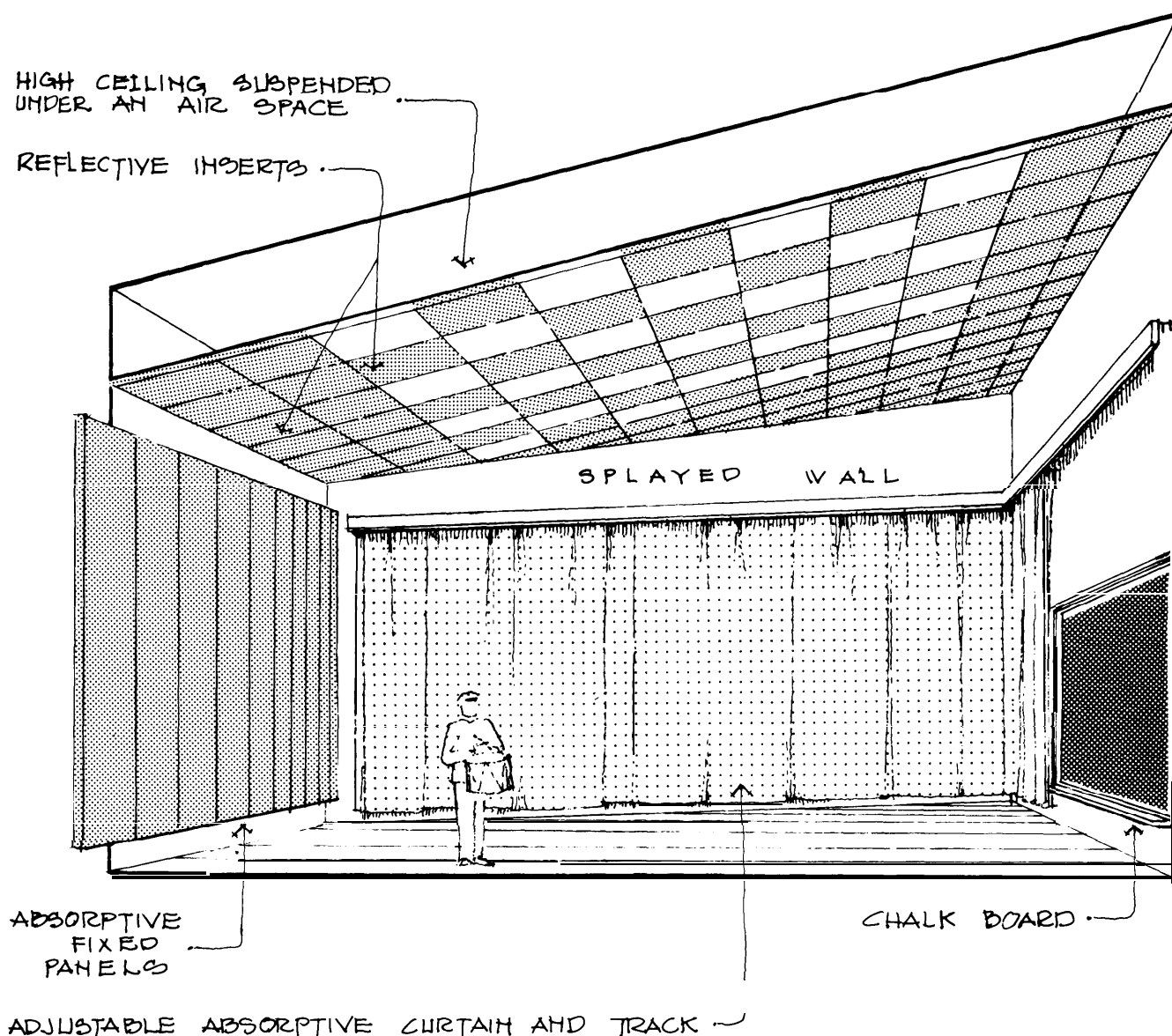
The basic guidelines regarding placement of absorptive materials are: (1) always treat the ceiling, most usually with suspended acoustic tile; (2) always treat at least the equivalent of one wall, but preferably spread the treatment over several walls; (3) if any two walls are parallel, treat one or both so that no major opposite and parallel surfaces remain hard. In general, this will assure a sufficient quantity of absorptive material (for loudness and reverberation control), a fair state of diffusion in that the absorbers are distributed throughout the room, and adequate flutter control.

Floors may be carpeted, but do not need to be. As indicated in Table 5-4, carpet is a poor absorber. Adding it to the other, required absorbers (on the walls and ceiling) will afford little additional control.

Table 5-4 Approximate Acoustical Absorptivity of Room Finishes and Treatments

	<u>NRC*</u>
Floor Finishes:	
All hard and rigid finishes	0.05
Wood on joists	0.10
Average glue-down carpet	0.25
Thick carpet without underpad	0.35
Thick carpet with underpad	0.45
Wall Finishes:	
Brick, drywall, etc.	0.05
Painted concrete block	0.10
Unpainted concrete block	0.25
Medium-weight curtains	0.45
Tectum or similar (average)	0.50
Heavy curtains	0.60
Mineral fiber wall panels	0.60
Glass fiber wall panels (1")	0.75
Tectum over glass fiber	0.80
Glass fiber wall panels (2")	0.90
Ceiling Finishes:	
Concrete, steel deck, etc.	0.05
Suspended plaster or drywall	0.05
Wood boarding	0.10
Mineral fiber tile - minimum	0.50
Fibrous spray (1", well applied)	0.65
Acoustical deck systems (average)	0.65
Mineral fiber tile - maximum	0.80
Well-perforated metal pan with insulation	0.85
Glass fiber ceiling board	0.90

*Higher number indicates better performance. See 5-4.A for definition of NRC.



ADJUSTABLE ABSORPTIVE CURTAIN AND TRACK

Figure 5-21. Room Acoustics in Main Rehearsal Room

B. Room Shape

The shaping of rooms for band practice and rehearsal was discussed in 3-5.C. In summary, the basic recommendations regarding room shape are: (1) avoid perfectly square or cube-shaped rooms, especially when designing small music rooms; in other words, let the principal dimensions be unequal; (2) if possible splay one or more of the major surfaces, although with proper absorptive treatments, this is not always necessary; (3) avoid concave shapes that will focus sound; (4) be generous with size, specifically with ceiling heights.

C. Main Rehearsal Room

The design shown in Figure 5-21 illustrates the major room acoustics design issues for Main Rehearsal Rooms. This space combines ample height with non-rectangular geometry and incorporates fixed as well as variable absorbers.

The floor is flat and bare, allowing great flexibility in the arrangement of band personnel. The ceiling is largely absorptive—at all frequencies including the lows, because it is suspended over an airspace. The reflective inserts in the ceiling (minimum 4' x 4' each) help players hear each other and also blend the sound as heard by the bandleader.

Assuming part of one major wall (usually the front wall) is covered by chalk or tack boards and thus must remain reflective, the opposite wall is permanently absorptive. Mounting the absorptive panels several inches off the wall, as noted, or backing them with batt insulation, which will add thickness to the treatment, increases absorptivity. The remaining walls—splayed in this example—can be covered with curtains or remain exposed, to suit acoustical preferences. The curtains could also cover the chalkboard if more absorption is required. Note that the curtains preferably should be sewn in individually movable panels, each up to 10' wide when extended. This permits locating cur-

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tains anywhere along a track, without necessarily covering a whole wall.

Attention should be paid to the durability and maintainability of materials. As shown in Figure 5-21, the wall treatments extend almost down to the floor, which they must, because otherwise there would be a zone of uncontrolled reflections between the lower, untreated walls. This requires particularly durable facing over the fiberglass panels. Curtains can be replaced more readily than panels but if their durability is a real concern, their extent could be limited from the track (at or near the ceiling) down to about 7' above the floor. In such a case, fixed treatment may be required on the lower portion of the wall.

D. Group Practice Rooms

The recommended treatment of Group Practice Rooms falls in between that of Main Rehearsal, described above, and Individual Practice, which follows. Large Group Practice Rooms should be similar to Main Rehearsal Rooms, except reflective inserts in the ceiling normally are not required. Curtains for variability remain advisable. Small Group Practice Rooms might more resemble Individual Practice, with no or minimal acoustical variability.

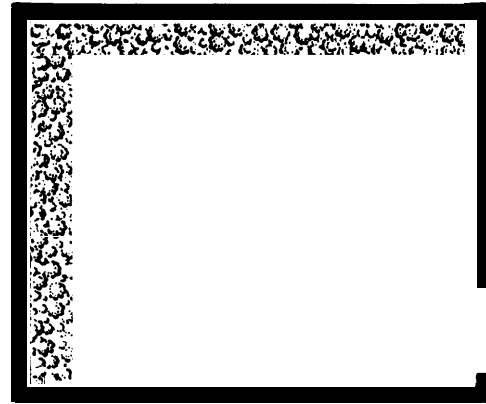
E. Individual Practice Rooms

The recommended treatment of Individual Practice Rooms is a smooth, hard floor, with a suspended acoustic tile ceiling. Some wall treatment is recommended regardless of room shape; and it should be at least 4' high, starting about 2'-6" above the floor, which puts it in the height range of musicians' instruments and ears. The first rule in locating the treatment is to eliminate flutter, as described in Figure 5-22. Although distribution across several walls is desirable for improved diffusion, Individual Practice Rooms are generally too small to allow a "patchwork" of reflective and absorptive surfaces.

It should be remembered that some ceiling materials only absorb sound. These include fiberglass lay-in panels, which are extremely absorptive (NRC 0.90). If, however, the suspended ceiling also must attenuate sound (for example, if it is hung below a continuous deck), then the choice is limited to attenuation-rated tiles and panels, which are made of mineral fiber, often foil-backed. They are less absorptive (NRC 0.60), but still adequate in most cases.

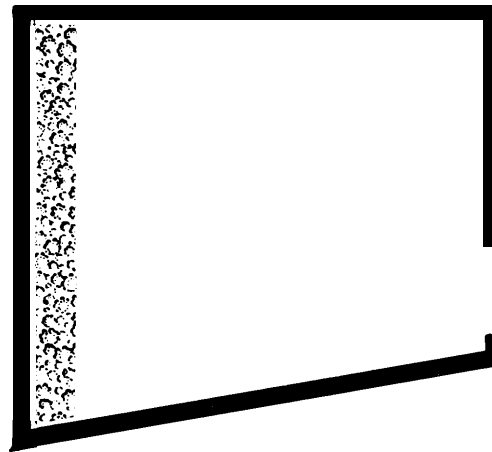
Prefabricated practice modules require no additional treatment. Their design incorporates ample areas of very absorptive finishes—most typically, perforated metal over several inches of fiberglass. Because of this and because of their confined size, they are even more "dead" than conventionally built practice rooms, treated as recommended.

A. ABSORPTION TREATS FLUTTER AND ECHO



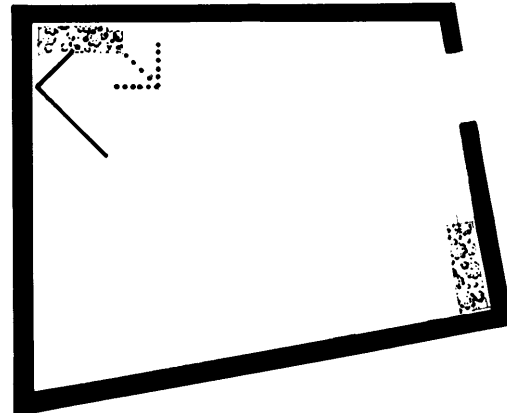
A. Flutter treated with absorption

B. ONE WALL SPLAYED - ONE OF PARALLEL WALLS ABSORPTIVE FOR ELIMINATING FLUTTER



B. Flutter treated with absorption and a splayed wall

C. SPLAYED WALLS ELIMINATE FLUTTER; ABSORPTION FOR ECHO IN 90° CORNER



C. Corner echo eliminated with absorption; flutter eliminated with wall splays

Figure 5-22. Absorption and Room Shape to Treat Acoustical Problems